Inventory Effects on Aggregate Timber Supply
by
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Abstract

Separate literatures exist to describe responses of timber owners and aggregate timber supply to product prices. While few investigators have alluded to the effects of varying inventory quality and ownership mix on the aggregate response, it is possible to describe how the responsiveness to prices can vary over time as the vintage of the timber inventory shifts. We estimated a probit harvest model using stand-level periodic forest inventory data and modeled the effects of price changes on aggregate supply. The stand-level data were obtained from fixed plots from loblolly pine stands in the coastal plain of North Carolina. By applying the estimated harvest decision model to each stand and multiplying product volumes by associated area expansion factors, we observed the effects of price perturbations on aggregate harvest quantities. The harvest model included data on sawtimber and pulpwood volumes, which enabled a simulation of the effects of changes in either product price or inventory characteristics on the production of pulpwood and sawtimber. To illustrate the effects of varying inventory characteristics, we evaluated harvest responsiveness in two periods. First, we calculated the supply elasticity with respect to price given the inventory of 1983-1989. Then, using alternative estimates of timber supply characteristics existing in 1995, we estimated the supply elasticity with respect to price given the inventory of 1989-1995. Differences in supply responses between the two periods are traced to evolving inventory vintages and changing quantities of inventory under NIPF and industry management.

INTRODUCTION

Timber supply responds to market signals through the myriad private and public decisions to harvest a portion of timber inventories. The aggregate response to price is, therefore, a function of biology, the environment, the characteristics of the inventory, and the objectives of the harvest decision makers. There is a substantial research literature on the harvest responsiveness of individuals to market signals, given forest and owner characteristics. Simultaneously, there is a separate research literature devoted to how market signals engender aggregate responses (see Wear and Parks, 1994). But because the mix of ownerships and the characteristics of the resource can vary substantially across gradients of space and time, both lines of research seem incomplete. This is particularly evident when considering the supply responsiveness at smaller geographic scales or when evaluating the aggregate effects of market signals when there are large differences in the resource across either time or space.

The following pages report our attempts to better understand the role of inventory characteristics and ownership mix in determining responses to timber price. We apply a harvest response/timber supply model to estimate aggregate supply elasticities by ownership and product for two periods: (i) 1983-1989, for which United States Forest Service's Forest Inventory and Analysis inventory data exist, and (ii) 1989-1995, for which inventory data for 1995 were projected using harvest estimates and a volume growth model. We then describe how the inventory changes could result in changes in responsiveness for each ownership group and for the region as a whole. The concluding paragraphs of our paper summarize and explain what we believe to be the implications of our findings for further modeling and for policy analysis.

METHODS

To estimate the effects of inventory characteristics on timber supply, we used a harvest choice/timber supply model developed by Prestemon and Wear (1998). This model is based on a representative sample of coastal pine forests in North Carolina to estimate harvest choices and uses an area frame sample of the region--forest inventories conducted by the USDA Forest Service--to infer regional harvest responses to changes in supply determinants. The individual stand harvest decision was modeled as a binary choice: to harvest or not to harvest, given a set of landowner and site characteristics. Area expansion factors defined by the area frame sample were then used to estimate the aggregate supply effects of estimated harvest probabilities as shown by Hardie and Parks (1991) in their analysis of regeneration levels in the South. Simulations of harvest probabilities were used to predict the effects of changing prices on aggregate timber supply.

Figure 1 defines the general methodology of

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our timber supply model. The model evaluates timber supply directly from FIA plots using inventory and timber price data. For each plot, the following procedure is completed:

1) Data describing the plot--inventory volumes, slope, distance to road, etc...--and timber prices are defined.
2) Current values of timber are calculated using volume and price data.
3) Future volumes (i.e., values at the end of the survey cycle) are forecast based on a growth model and future values are calculated by applying estimated prices.
4) The probability of harvest is estimated using a harvest choice model that takes current and future timber values and other site conditions as arguments.
5) Area expansion factors for the plot are applied to forecast the harvest response for the forest area represented by the plot.

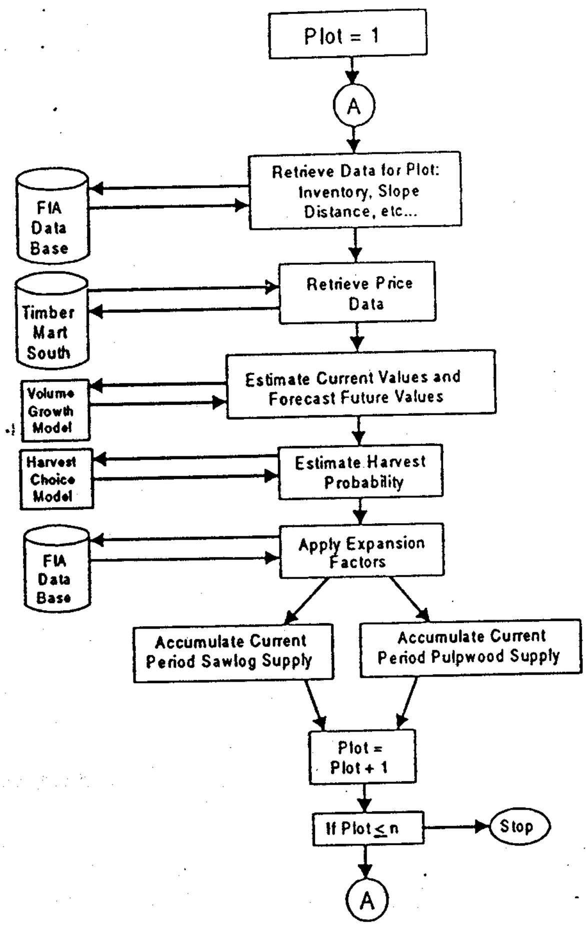
By completing steps 1-5 for all plots in the inventory, a total supply response was estimated for a given price/inventory scenario.

Timber supply elasticities were estimated by changing prices in the current or the terminal period or in both and calculating the change in expected harvest response. These various scenarios therefore give insights into harvest responses for price changes that are perceived as temporary or permanent. Confidence intervals for the elasticity estimates were calculated using a bootstrap method described in Efron (1987). Details regarding the modeling approach are contained in Prestemon and Wear (1998).

To evaluate the effects of changes in inventory, we simulate two sets of scenarios. The first, which we call the "actual inventory scenario," evaluates supply elasticities at the beginning and the end of a survey cycle. This demonstrates the differences in supply response implied by observed changes in the forest inventory for our study area.

The second set of scenarios simulates the effect of harvests on the forest inventory by linking changes in harvest response in period one to the starting inventory for period two. We call this the "simulated inventory scenario." This scenario provides a means of examining the effect of the harvest response to price on the future price-responsiveness of subsequent harvests. This provides a direct measure of how supply response could evolve over time as inventories adjust.

Figure 1. Flow chart of timber supply model based on plot-by-plot analysis of harvest choices.



DATA

Data for all variables except timber prices were taken from FIA surveys 5 and 6 of the Coastal Plain of North Carolina. The unit of observation was the individual permanent survey plot. Plots were measured during the summers of 1983 and 1989 so that the period for our analysis was 6 years. The following variables were taken directly from the plot records: survey 5 standing volume of pulpwood and sawtimber (cubic feet), survey 6 standing volumes, the distance to the nearest road (feet), and a dummy variable indicating whether or not the stand was harvested between surveys 5 and 6. In addition, to estimate the volume growth equations, we recorded stand age (years), basal area (ft^2acre^{-1}), and site index (base age 50 years) as measured in survey 5. The indication of harvest was defined by FIA: the removal of the vast majority of merchantable timber on the site. Stands that either experienced no significant timber harvesting activities and stands with FIA harvests accounted for about 90 percent of plots qualifying as remeasured and majority southern pine in the coastal plain of North Carolina. The remaining 10 percent of plots included those that experienced some harvesting but not what FIA would describe as a harvest. These remaining stands underwent other kinds of partial cutting, which we decided not to model. These stands, and hence this proportion of timber growing in the region, were ignored in the empirical results that we report.

Stumpage price data were taken from Timber Mart South (Norris Foundation 1977-1986). Real stumpage prices in both periods were taken as $6.80cd^{-1} ($3.0m^{-3}) for pulpwood and $88.24mbf^{-1} ($19.4m^{-3}) for sawtimber. We assumed that prices were essentially constant between 1983 and 1989. This, we believe, is justified: during a period when price expectations could have been developed for the future (say, between 1977 and 1986), real prices for these products fluctuated widely around averages: a 2.3% annual decrease in price for pulpwood (with a 7.9% standard deviation) and a 1.3% annual increase for sawtimber (with a standard deviation of 17.9%) (Norris Foundation, 1977-1986).

RESULTS

The effects of changes in inventory are examined by comparing elasticities of supply by ownership for the two inventory periods, 1983-1989, and 1989-1995. Table 1 shows responses to price changes at the beginning of the survey ("initial"), end of the survey ("final"), and both the beginning and end of the survey ("permanent") for the "actual inventory scenario." That is, the responses shown take harvests and stand state in 1989 as given for the second period, 1989-1995. Hence, for this table's listing of supply elasticities, harvest responses to price changes modeled for 1983-1989 do not affect the stands existing in 1989. This allows us to examine historical changes in the supply responses.

The elasticity of supply for a temporary price change (initial price) is universally positive and significant for both industry and NIPF ownerships (Table 1). Industry's supply elasticity is generally twice that of the NIPF group, indicating a stronger response to market signals. For both owners and both products (pulpwood and sawtimber), supply responds more strongly to sawtimber prices than to pulpwood prices. This seems consistent with the higher value of sawtimber and the longer production period. It indicates as well the high degree of jointness in producing the two products.

Contrasting supply elasticities between the first and second periods provides insights into how forest management has changed the quality of forests. Results differ by ownership group. For the NIPF group, there is no significant difference in the supply elasticities modeled for periods one and two, suggesting no qualitative difference in the product/vintage distributions of these forests. However, on industry land, supply elasticities are significantly higher for all product:price combinations in period 2. This indicates that forest management on these lands has enhanced the short-run timber supply potential over the 1983-1989 survey period.

Harvest responses to an anticipated change in price (final price) shows that current harvest would be reduced as the returns to delaying harvest increase (Table 1). All supply elasticities are negative and significant at the ten percent level. In general, the values of the supply elasticities for final price are simply the inverse of those for initial price, indicating symmetry in the responses to perceived value changes. Differences between owners and between periods are mirrored in these results.

Current period supply elasticity with respect to a simultaneous shift in final and initial prices is essentially equal to the sum of elasticities for the two prices separately. The signs of these elasticities (Table 1) vary across product:price combinations and between ownership groups, and many are insignificant, especially for industry. In general, there is a greatly dampened response to permanent price increases than to anticipated or temporary price changes. Furthermore, there is no generalizable finding for the differences between ownership groups nor between periods.

Table 2 shows the effects of price changes on product supply elasticities, with modeled price changes affecting the stand state in 1989. Therefore, the 1989 stand volumes were those produced by the harvest models applied to the 1983-1989 data. For example, if the probability of harvest for stand *j* in the 1983-1989 period was 0.26, then 0.26 stand *j*'s were cut and started from bare land when growing into the next survey cycle, 1989-1995, while 0.74 stand *j*'s were not cut and were allowed to grow into the next survey cycle, given the stand volumes expected to exist without cutting.

Table 1. Average 1983-1989 and 1989-1995 elasticity estimates, given actual inventory changes during 1983-1989, 500 bootstraps.					
Supply Quantity	Changed Price	NIPF		Industry	
		1983-1989	1989-1995	1983-1989	1989-1995
Pulpwood	Initial Pulpwood	0.29 *** (0.11)	0.34 *** (0.11)	0.98 *** (0.19)	1.94 *** (0.28)
Pulpwood	Initial Sawtimber	2.90 *** (1.09)	3.02 *** (1.14)	4.56 *** (1.55)	9.94 *** (2.69)
Sawtimber	Initial Pulpwood	0.23 *** (0.08)	0.24 *** (0.08)	0.57 *** (0.21)	1.16 *** (0.34)
Sawtimber	Initial Sawtimber	4.57 *** (1.66)	4.79 *** (1.86)	10.21 * (6.22)	16.03 ** (6.75)
Pulpwood	Final Pulpwood	-0.18 * (0.10)	-0.22 ** (0.11)	-1.11 *** (0.24)	-1.92 *** (0.31)
Pulpwood	Final Sawtimber	-3.20 ** (1.28)	-3.38 *** (1.30)	-6.36 *** (1.90)	-13.64 *** (3.05)
Sawtimber	Final Pulpwood	-0.18 ** (0.07)	-0.19 ** (0.08)	-0.63 ** (0.25)	-1.16 *** (0.37)
Sawtimber	Final Sawtimber	-5.09 *** (1.75)	-5.32 *** (1.86)	-11.60 * (7.00)	-18.94 ** (7.68)
Pulpwood	Permanent Pulpwood	0.11 *** (0.02)	0.12 *** (0.02)	-0.13 * (0.08)	0.02 (0.10)
Pulpwood	Permanent Sawtimber	-0.30 (0.27)	-0.36 (0.27)	-1.80 *** (0.57)	-3.71 *** (0.72)
Sawtimber	Permanent Pulpwood	0.05 *** (0.01)	0.05 ** (0.02)	-0.06 (0.07)	0.00 (0.12)
Sawtimber	Permanent Sawtimber	-0.53 * (0.28)	-0.54 * (0.29)	-1.42 (0.96)	-2.96 ** (1.16)

Notes: Standard errors in parentheses; asterisks indicate significance at 10 (*), 5(**), and 1(***) percent.

Table 2. Average 1983-1989 and 1989-1995 elasticity estimates, given inventory changes defined by 1983-1989 harvests, 500 bootstraps.

Supply Quantity	Changed Price	NIPF		Industry	
		1983-1989	1989-1995	1983-1989	1989-1995
Pulpwood	Initial Pulpwood	0.25 *** (0.09)	-0.06 ** (0.03)	0.83 *** (0.15)	-0.11 * (0.06)
Pulpwood	Initial Sawtimber	2.52 ** (0.98)	-0.61 * (0.37)	3.76 *** (1.44)	-1.05 (0.70)
Sawtimber	Initial Pulpwood	0.22 *** (0.07)	-0.08 ** (0.04)	0.61 *** (0.18)	-0.18 * (0.10)
Sawtimber	Initial Sawtimber	4.27 *** (1.57)	-1.41 * (0.75)	9.22 * (5.44)	-3.94 (3.21)
Pulpwood	Final Pulpwood	-0.14 (0.09)	0.28 ** (0.13)	-0.96 *** (0.17)	2.01 *** (0.29)
Pulpwood	Final Sawtimber	-2.72 ** (1.14)	3.16 ** (1.45)	-5.39 *** (1.70)	9.18 *** (2.71)
Sawtimber	Final Pulpwood	-0.17 ** (0.07)	0.30 ** (0.12)	-0.69 *** (0.21)	1.69 *** (0.33)
Sawtimber	Final Sawtimber	-4.77 *** (1.67)	6.07 ** (2.56)	-10.67 * (6.06)	18.38 ** (8.33)
Pulpwood	Permanent Pulpwood	0.11 *** (0.01)	0.08 *** (0.01)	-0.13 ** (0.06)	-0.13 (0.10)
Pulpwood	Permanent Sawtimber	-0.20 (0.23)	-0.18 (0.22)	-1.63 *** (0.40)	-3.59 *** (0.50)
Sawtimber	Permanent Pulpwood	0.05 *** (0.01)	0.02 *** (0.01)	-0.08 (0.06)	0.02 (0.08)
Sawtimber	Permanent Sawtimber	-0.51 * (0.27)	-0.49 * (0.25)	-1.48 * (0.80)	-2.87 *** (0.71)

Notes: Standard errors in parentheses; asterisks indicate significance at 10 (*), 5(**), and 1(***) percent.

Because price perturbations in the first survey period (initial, final, permanent) perturbed harvest probabilities, these perturbations affected the stand state in 1989 and therefore the harvests in the 1989-1995 period.

The first four rows of results in Table 2 show the effects of a temporary price increase in 1983 on the supply of timber offered in both 1983-1989 and 1989-1995. The large temporary stimulating effects of the price increase for sawtimber harvests in 1983-1989, translated into lower harvests in 1989-1995. Similarly, large price increases in 1989 meant that harvests were lower in the 1983-1989 period through the effects of higher value growth rates but the opposite in 1989-1995. In fact, because harvests were so much lower for the 1983-1989 period, larger volumes were available and affected by the changed values and costs, calling for a larger price response than that shown for an initial price change in the first survey period. Responsiveness almost doubled for both industry and NIPF owners.

Permanent price changes, perhaps relevant to owners who view timber prices as a random walk, in this arrangement of harvest response modeling show that, for NIPF owners, responsiveness to prices was unchanged between the two periods: pulpwood harvest quantity would increase by 0.2 percent for each 1.0 percent increase in pulpwood price, and sawtimber harvest quantities would decrease by about 0.5 percent in response to a sawtimber price increase. For industry, there is evidence that while the responses to pulpwood prices were relatively similar in both periods, responses to sawtimber prices became more elastic. Pulpwood supply elasticities with respect to sawtimber price declined from -1.6 to -3.5, while sawtimber supply elasticities with respect to sawtimber price declined from –1.5 to -2.9.

CONCLUSIONS

These results have implications for timber supply modeling. Significant differences in price elasticities estimated for actual changes and for simulated changes in forest inventories raise several issues for aggregate supply modeling. Supply models could be enhanced by including: (i) separate measures of the available pulpwood inventory and the available sawtimber inventory, since sawtimber stands have some pulpwood volume and because separate measures define opportunity costs and values changes over time; (ii) sawtimber as well as pulpwood market prices, due to the opportunity costs and joint production (consistent with Newman, 1987, and Newman and Wear, 1993); (iii) some measure of the vintage of the sawtimber growing stock, since older stands have larger trees that grow in value more slowly and hence are more price-sensitive. For both pulpwood and sawtimber supply, empirical specifications might be more precise if interaction terms were included.

Sawtimber supply was found to be negatively related to permanent changes in sawtimber price, given a constant timberland base. This effect was related to the higher value growth automatically obtained by increasing the sawtimber price, giving owners an added incentive to grow stands to older ages. Because we did not attempt to grow stands further into the future, we could not observe the ultimate effects on sawtimber production, which might be positive. Higher sawtimber prices also seem to mean lower pulpwood production. Higher pulpwood prices mean slightly higher pulpwood production in that fixed timberland base, as well.

In a general sense, the ambiguous (and sometimes insignificant) elasticities of supply with respect to permanent prices is consistent with the theory of optimal rotations. Single stand models of harvest choice (in the manner of Faustmann) indicate that permanent price changes lead to no changes in rotation length when there are no stand-establishment costs (e.g., Hyde, 1980). With those costs included, the rotation is sensitive to the ratio of cost to price, but these effects are dominated by value growth rates that are unaffected by a permanent price change. Harvest timing, therefore, remains relatively insensitive to the price change.

It seems probable that both sawtimber and pulpwood supply should be positively related to their own prices in the long run (and pulpwood supply to sawtimber price, as well), if the land base for growing timber is allowed to expand: higher timber prices mean that timber production is profitable on a larger land base (Hyde, 1980; Parks and Murray, 1994; Plantinga, 1996). Further, our models did not include inputs in the growth model specification. Higher timber prices should be related to production inputs other than timber capital and land. If timber is a normal good and the amount of land is fixed, then higher prices should induce higher inputs of other factors (e.g., labor, fertilizers, genetic improvements), yielding higher output volumes and a long-run positive price response. A more complete model, then, would include investment as well as harvest responses.

Yet another view is that because prices may be viewed by some owners as stationary and other owners as nonstationary, the aggregate response to timber price changes will depend not only on the available inventory and ownership mix, but also on the mix of perceptions regarding price dynamics. If timber prices are viewed as stationary by owners of the majority of timberland, then short-run aggregate price responses should dominate, and aggregate timber supply should be highly price-sensitive. If most timberland is owned by those who view prices as having no long-run level, then aggregate responses to short-run timber price changes would be muted.[2]

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[2]We thank Marc E. McDill for reminding us of this interpretation.

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